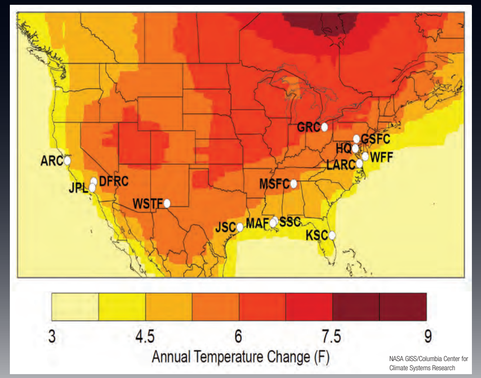
the setting

NASA Ames Research Center occupies approximately 1800 acres in California's Silicon Valley, along the southwest shore of San Francisco Bay, locally called the South Bay.

A technology-rich economy, renowned academic institutions, robust global trade links, and a comfortable climate have drawn almost 7 million people to the Bay Area. Temperatures in the Bay Area range from an average of 49°F (January) to 69°F (July – August). Sea breezes moderate the climate. Annual average precipitation is 15.5 inches, with most rain falling during the winter season.

climate change

Projected Temperature Change (°F), 2080s minus 1980s, A1B Emissions Scenario*



* A1B scenario, one of several developed by the IPCC, assumes high CO_2 levels for first half of the 21st century, followed by a gradual decrease in emissions after 2050

A Note about Downscaling Climate Data for Individual NASA Centers:

The quantitative climate projections in this document are based on global climate model simulations conducted for the IPCC Fourth Assessment Report (2007) from the World Climate Research Programme's (WCRP's) Coupled Model Intercomparison Project Phase 3 (CMIP3) multi-model dataset. The simulations provide results from sixteen global climate models that were run using three emissions scenarios of future greenhouse gas concentrations. The outputs are statistically downscaled to 1/8 degree resolution (~12 km by 12 km) based on outputs from the bias-corrected (to accurately reflect observed climate data) and spatially-downscaled climate projections derived from CMIP3 data. This information is maintained at: **http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections** and described by Maurer, et al. (2007).

The **rapid ice melt scenario** and qualitative projections reflect a blend of climate model output, historical information, and expert knowledge. For more information about rapid ice melt, see a paper and references at **http://www.nature.com/climate/2010/1004/pdf/climate.2010.29.pdf**.

Climate and impact projections--like all projections--are characterized by uncertainty, leading to a range of possible outcomes. Climate projection uncertainties include but are not limited to:

1) Future greenhouse gas concentrations,
2) Sensitivity of the climate system to greenhouse gas concentrations,
3) Climate variability, and,
4) Changes in local physical processes (such as afternoon sea breezes) that are not captured by global climate models.

Even though precise quantitative climate projections at the local scale are characterized by uncertainties, the information provided here can guide resource stewards as they seek to identify and manage the risks and opportunities associated with climate change and the assets in their care.

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Adapting Now to a Changing Climate

Ames Research Center

the issue

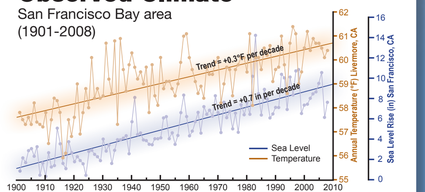
Data collected since the beginning of the 20th century in the Bay Area point to two undeniable facts: sea levels and temperatures are rising.

Climate change models, downscaled using data specifically from California, project continued sea level rise in San Francisco Bay and warmer temperatures. As the temperature warms, the Sierra Nevada snowpack, which is the major source of fresh water for the Bay Area, is expected to diminish in volume *and* melt earlier. These changes may impact water resources and energy reliability. The changing climate may also affect facility infrastructure, natural habitats, and quality of life. In fact, the California Natural Resources Agency, citing the seven-inch sea level rise along California's coast over the past century, has already published guidelines for a state-wide adaptation strategy that includes provisions for both short- and long-term responses.[1]

The hazard-specific local information and projections provided here can help area leaders (NASA, together with its tenants, neighbors, and area government partners) understand what they may expect in the future, and plan accordingly.

Observed Climate

San Francisco Bay area
(1901-2008)

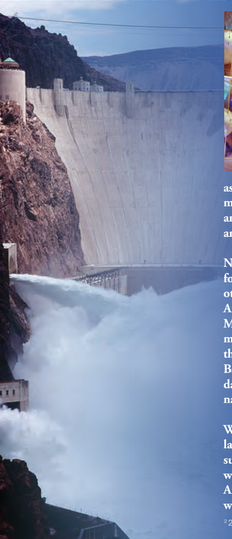


Temperature data are for Livermore and sea level data are for San Francisco. These two weather stations were chosen because they have full long-term data records. Temperature data (not shown) for the nearby stations of Moffett Field, Palo Alto, and San Jose show similar upward trends. All data are from the National Oceanic and Atmospheric Administration.

[1] 2009 California Climate Adaptation Strategy, California Natural Resources Agency

what's at stake?

NASA Ames generates $1.3B in annual economic output, supporting more than 8400 jobs, 5300 of which are in the Bay Area. The new NASA Research Park, to be fully built out by 2025 as an integrated research and education endeavor, will generate an additional 3000 jobs nationally and $5.8B in annual economic impact.[2] Ames leads NASA advances in the areas of astrobiology, small satellites, robotic lunar exploration, the search for habitable planets, supercomputing, intelligent/adaptive systems, advanced thermal protection, and airborne astronomy. The unique



assemblage of expert personnel and research facilities, with the many complementary assets of the Silicon Valley's high-tech and university communities, produce an unparalleled research and innovation powerhouse.

NASA Ames Research Center includes the majority of the former Naval Air Station Moffett Field. The Center contains other Federal and non-Federal tenants including the California Air National Guard, US Army, and Federal Emergency Management Agency. Moffett Federal Airfield is used by military and emergency response agencies for actions critical to the Nation and by NASA for research. The other airports in the Bay Area are built on fill material and thus may be vulnerable to damage from earthquakes. Moffett Federal Airfield is a critical national asset, especially in times of emergency response.

With approximately 281 acres of protected, undeveloped land, Ames is also host to several rare or endangered species, such as the California clapper rail, salt marsh harvest mouse, western pond turtle, and burrowing owl. The protected land at Ames includes significant expanses of tidal marsh – freshwater wetland – upland grass ecosystem.

[2] 2010 Economic Benefits Study – NASA Ames and NASA Research Park

projected changes

The Climate Science Context

Scientists have collected weather data and indicators of longer-term climate patterns (such as ice cores and tree rings) from the entire globe. Based on analyses of these data, plus a growing understanding of physical processes that control climate, scientists have developed sophisticated models that project future climate changes. Climate scientists have reached a consensus that some climate changes will accelerate this century, leading to a range of corresponding climate impacts. The US Global Climate Change Research Program's report summarizes these results at www.globalchange.gov/publications/reports/scientific-assessments/us-impacts. NASA climate scientists are an important part of the international research effort. NASA is a key player in climate modeling and collection of both Earth-based and space-based data used to develop and validate climate models.

Climate Scenarios

The United Nations Intergovernmental Panel on Climate Change (IPCC) developed three greenhouse gas emissions scenarios based on differing sets of assumptions about economic growth, population growth, and other factors. The emissions scenarios range from "status quo" (i.e., minimal change in the current emissions trends) to more progressive (i.e., international leaders implement aggressive emissions reductions policies). From each of these three scenarios, a corresponding GHG atmospheric concentration is calculated and input into a global climate model. Scientists assess the range of model results to project future climate. The climate models include atmosphere, land surface, ocean, and sea ice components.

The Bay Area Climate Today

Climate changes will be superimposed on the large variations that characterize the Bay Area's climate today. For example, precipitation, measured per year or per decade, varies greatly because the area is influenced by variability in remote patterns of ocean surface temperature and atmospheric pressure (e.g., El Niño vs. La Niña years). The region also has many microclimates due to influences from the Pacific Ocean, San Francisco Bay, and nearby mountain ranges. Annual precipitation is relatively high near the coast and coastal mountains, and decreases to the east and south. Daily and seasonal temperature ranges grow with distance from the moderating effects of the ocean and the bay. Additional microclimatic factors include coastal fogs and ocean/bay land breezes.

Model results of projected changes

Climate Variables

Variable	Baseline	2020s	2050s	2080s
Average Temperature	59.9°F	+1 to 2°F	+2 to 4°F	+3 to 7°F
Annual Precipitation	15.5 in	-10 to +15%	-15 to +15%	-20 to +15%
Sea Level Rise	NA	+1 to 3 in	+6 to 9 in	+12 to 17 in
Sea Level Rise – Rapid Ice Melt Scenario (See Rapid Ice Melt text box for more detail)	NA	+4 to 8 in	+18 to 26 in	+41 to 49 in

Temperature and precipitation changes reflect a 30-year average centered on the specified decade; sea levels are averages for the specified decade. The baseline for temperature and precipitation is the most complete 30-year data period centered around the 1980s; the baseline for sea level is 2000-2004. The baseline temperature value is an average of baseline data from the Palo Alto, San Jose, Moffett Field, and Livermore stations. The baseline average for precipitation is from Livermore, Palo Alto, and San Jose. Sea level projections are for San Francisco Bay. Temperatures are rounded to the nearest half degree, precipitation to the nearest 5%. Data are from the NOAA National Climatic Data Center.

Projected Changes

NASA's Goddard Institute for Space Studies used site-specific climate data (temperature and precipitation) from four stations in the region, and sea level rise data from San Francisco to downscale the climate models to yield projections for the southwestern San Francisco Bay area. Overall, the projections for the Bay Area indicate higher mean temperatures and rising mean sea levels, but fairly consistent annual precipitation. Because of its location along the shoreline of the Bay, sea level rise may pose the largest threat to Ames. Large changes in the frequency of some extreme events like hot and cold days (see tables below), may also lead to large impacts.

Additional Risk Considerations for Adaptation Planning

Because the region depends on remote sources such as the Sierra Mountains for much of its water and energy needs, climate projections must consider broader regions as well. Earthquakes are a significant hazard in the region, but are unrelated to climate; however, earthquake preparation and response planning may make the area more resilient with regard to impacts of extreme storm events (e.g., power outages, flooding, fires, etc.)

A Note on Interpreting Climate Projections

Do the projections in the Climate Variables chart mean it is appropriate to say, "In 2043, the average temperature at Ames will be 63°F"? No. Models do not provide this degree of absolute certainty.

Rapid Ice Melt Scenario

Because General Circulation Models do not capture all of the processes that may contribute to sea level rise, an alternative method that incorporates observed and longer-term historical ice-melt rates was developed. This "rapid-ice melt" approach includes the potential for rapid melting of some of the **land-based ice** in polar regions, such as that on Greenland or the Western Antarctic Ice Sheet. **This approach suggests that sea level could rise in the San Francisco Bay by approximately 41 to 49 inches by the 2080s.**

Still, they suggest a significant and progressive long-term warming trend that could have considerable impacts on life and work in the Bay Area; more specifically, it is appropriate to say that models suggest that between 2040 and 2070, temperatures may increase 2 to 4 degrees above the average baseline temperature.

Daily Temperatures	Location	Baseline	2020s	2050s	2080s
Max temperature at or above 90°F (days)	Livermore	59	63 to 72	71 to 86	78 to 104
	Moffett Field	9	10 to 13	13 to 18	16 to 29
Min temperature at or below 40°F (days)	Livermore	94	70 to 80	55 to 70	37 to 63
	Moffett Field	32	18 to 24	10 to 19	5 to 14

Qualitative Changes in Extreme Events During This Century

Event	Direction of Change	Likelihood
Heat Stress	↑	Likely
Intense Precipitation Events	↑	More likely than not
River Flooding	↑	Likely
Drought	↑	Likely
Intense Winds	Unknown	NA

Based on global climate model simulations, published literature, and expert judgment

The number of days per year exceeding 90°F is projected to rise dramatically in the coming century, and the number of days with temperatures below 40°F is projected to decrease. More hot days would affect outside work, energy use, agricultural practices, and habitats.

our responsibility

While leaders around the world are deliberating about the best ways to slow the rate of climate change through reductions in greenhouse gas emissions, ***the time to develop and implement adaptation strategies is now. Executive Order 13514 directs Federal agencies to assess and manage the effects of climate change on their operations and mission in both the short and long term.*** **Climate changes in the Bay Area will impact facility operations (e.g., storm water management, energy demand and supplies, cost of utilities), natural resource management (e.g., tidal marsh species recovery, invasive species control), mission infrastructure (e.g., labs, testing facilities, and computing capabilities), as well as the quality of life in the community (e.g., drinking water availability, wildfire risk). Abating critical impacts means planning for them well in advance, as part of established planning and budgeting cycles within and beyond NASA. Agencies will need to implement short-term tactical changes now, while simultaneously planning for longer term strategic adaptation measures. Some potential impacts are listed in the chart below.**

Ames's new Sustainability Base incorporates the latest green technologies and space technologies to create and demonstrate a one-of-a-kind office building.

Climate Variable	Potential Impacts
Sea Level Rise	Partial inundation of Center including portions of Airfield and storm water management system; inundation of transportation corridors; reduced emergency response capabilities; salination, disruption to South Bay Salt Ponds restoration program
Overall Increased Temperature	Increased cooling costs in the summer; decreased heating costs in the winter; potential stress to building materials and systems; increased algal blooms, with subsequent water quality impacts
Coastal Flooding	Increased coastal erosion of already limited sediment supply; impacts to wastewater treatment plants on the coast
Precipitation Changes	Reduced reliability of fresh water supply especially late in the water year from diminishing snowpack in Sierra Nevada range; reduced water flow for hydroelectric power late in the water year; possibility of increased flood risk during winter and spring